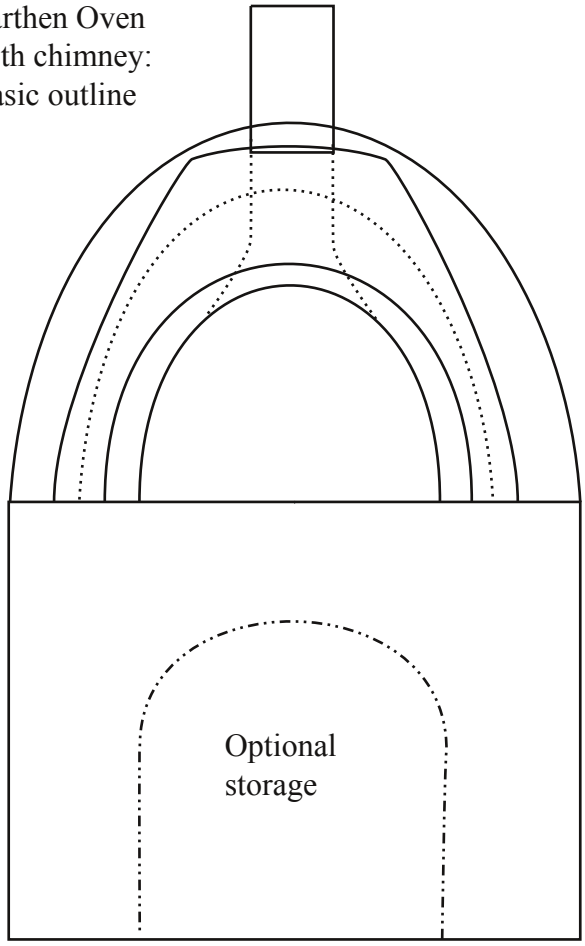
Two-Chamber Earthen Oven

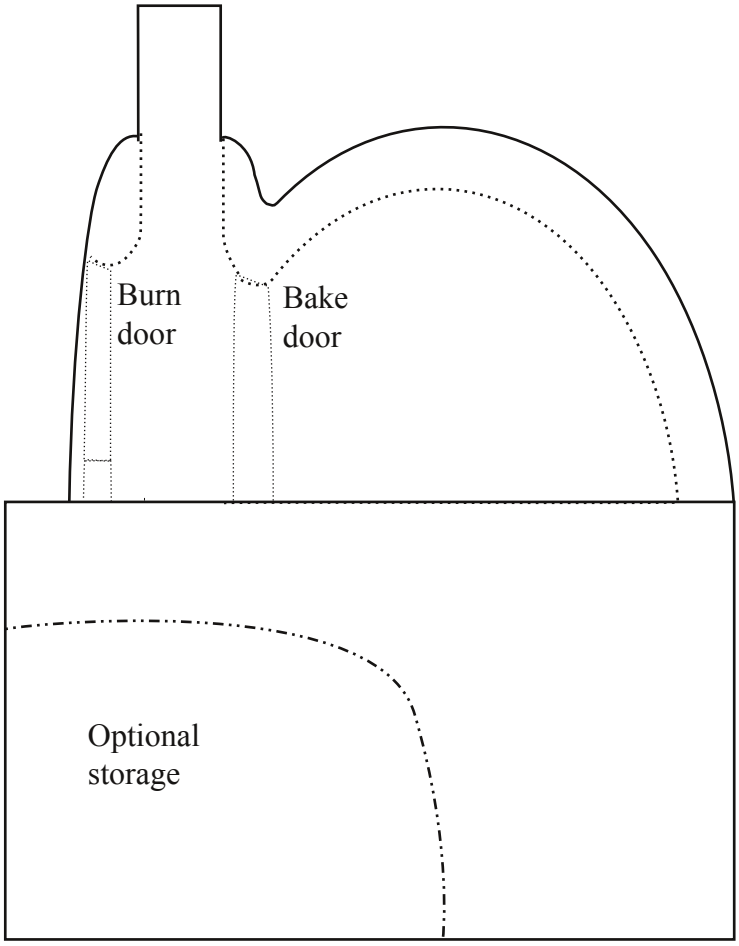
cob oven with chimney: plans and instructions

by Ernie & Erica Wisner

Building a cob oven: clockwise from upper right. www.ErnieAndErica.info

Earthen Oven
with chimney:
Basic outline



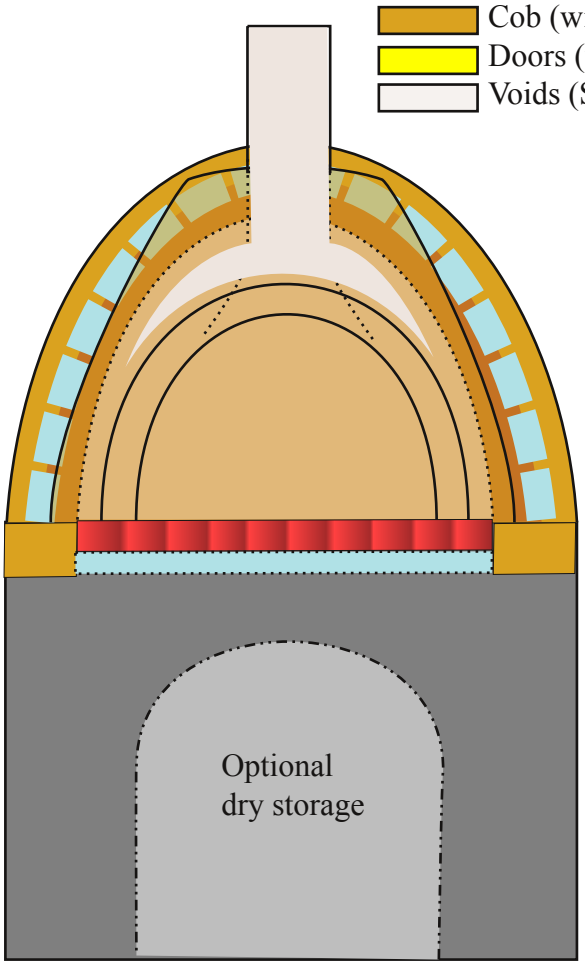


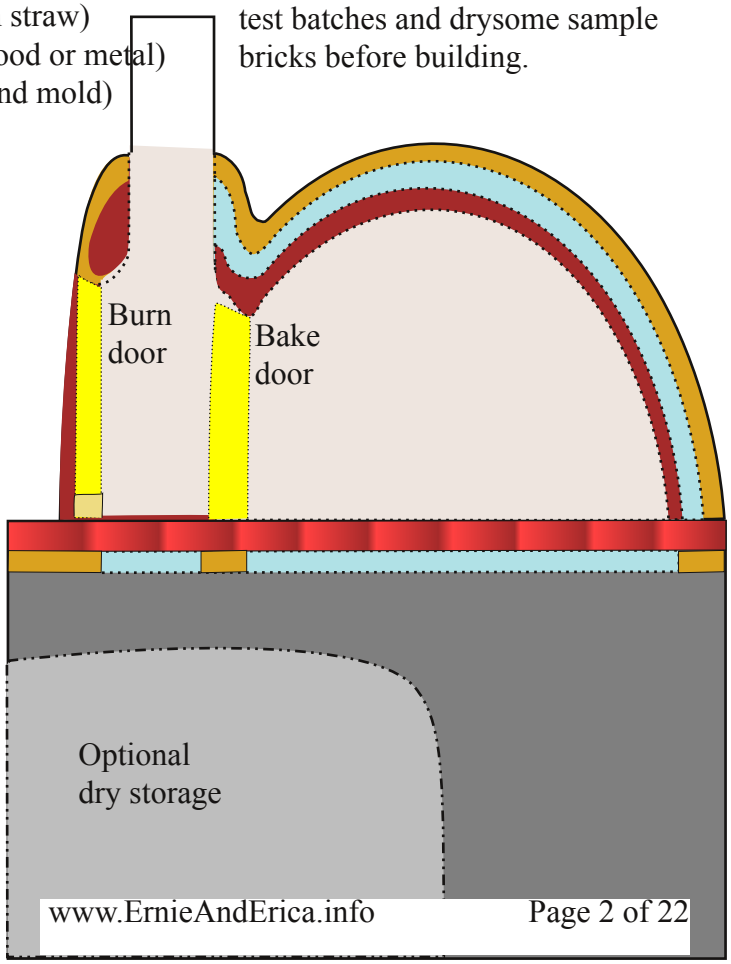
Earthen Oven materials:

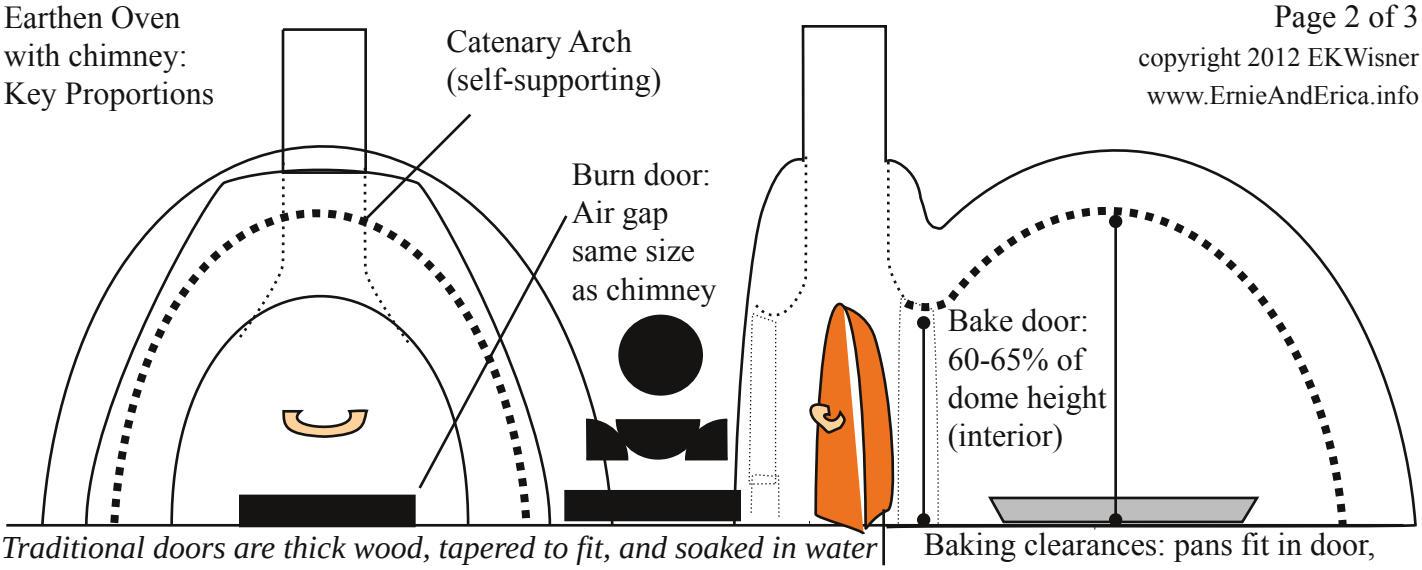
- General masonry
- Thermal lining / brick
- Insulation (perlite + clay)
- Cob (with straw)
- Doors (wood or metal)
- Voids (Sand mold)

Materials are described separately.

Best results depend on experience with local subsoils, so plan to make test batches and drysome sample bricks before building.

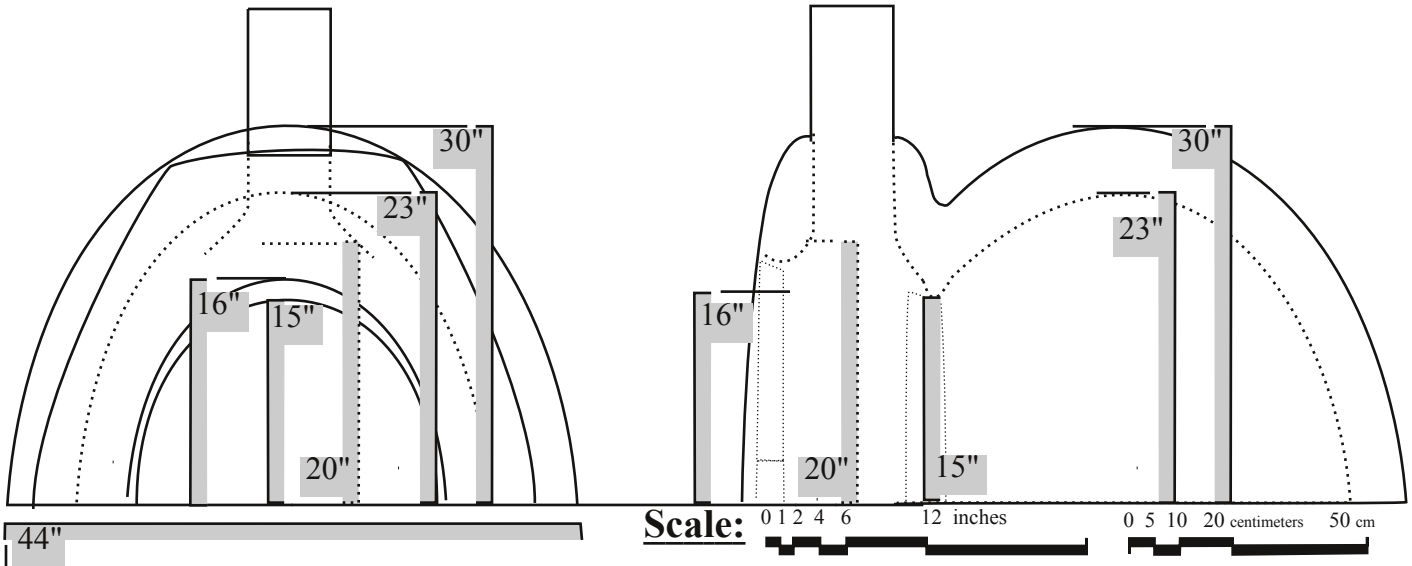


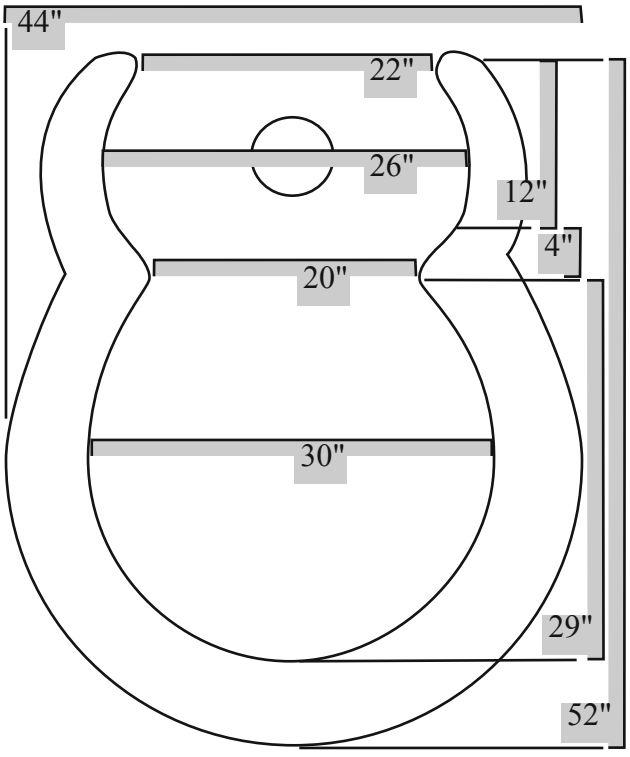




Traditional doors are thick wood, tapered to fit, and soaked in water before each use. When charred through, they are replaced.

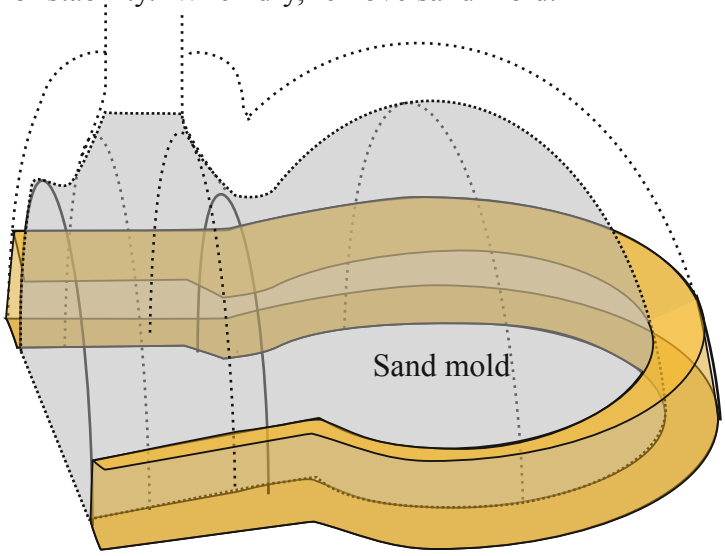
Baking clearances: pans fit in door, and can rotate inside oven.





Dimensions:	Inches	Metric
Smoke chamber 26" x 12"		66 x 30 cm
(Stovepipe 4", 5", or 6")		120 mm -150 mm
Chimney throat at 20" height		50 cm
Burn door 16" tall x 22" wide		41 x 56 cm
Oven (bake area) 30" x 29"		76 x 73 cm
Bake door 22" w x 15" h (x 2-3")		56 x 38 (x 6-7 cm)
Dome height 23"		58 cm
Outside dimensions:		
Length: 52 inches		132 cm
Width: 44 inches		112 cm
Height: 30 inches		75 cm
Wall thickness:		
Oven walls (insulated) 6" to 8"		15 - 20 cm
Smoke chamber - 3 to 4"		8 cm - 12 cm

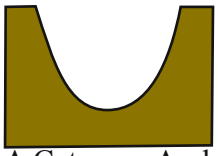
Building the Dome:
Work each layer in level courses, tilting inward, for stability. When dry, remove sand mold.



These drawings show a single, thick layer of cob, to illustrate the tilted courses. For a simpler project, you can build an oven just this way, with a single thick layer of straw / clay.

To build the three-layer oven as shown on page 1, be sure that each layer is only 1-2" thick. Though it is more work to build, most people prefer the performance of ovens with the three separate layers.

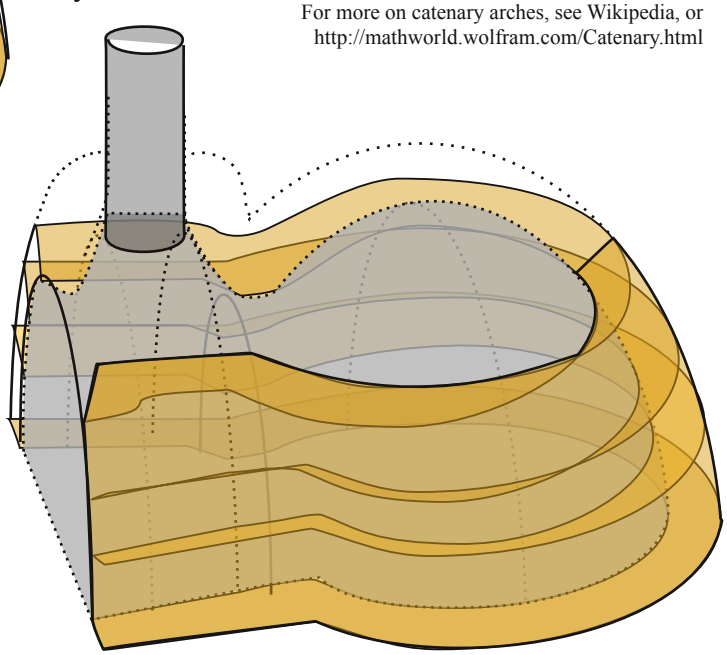
As you build, check the thickness often. If the walls slump or become too thick, do not try to push them back up. Instead, let the material dry slightly, then carve away the excess. The removed material can be mixed into the fresh batch and re-used.



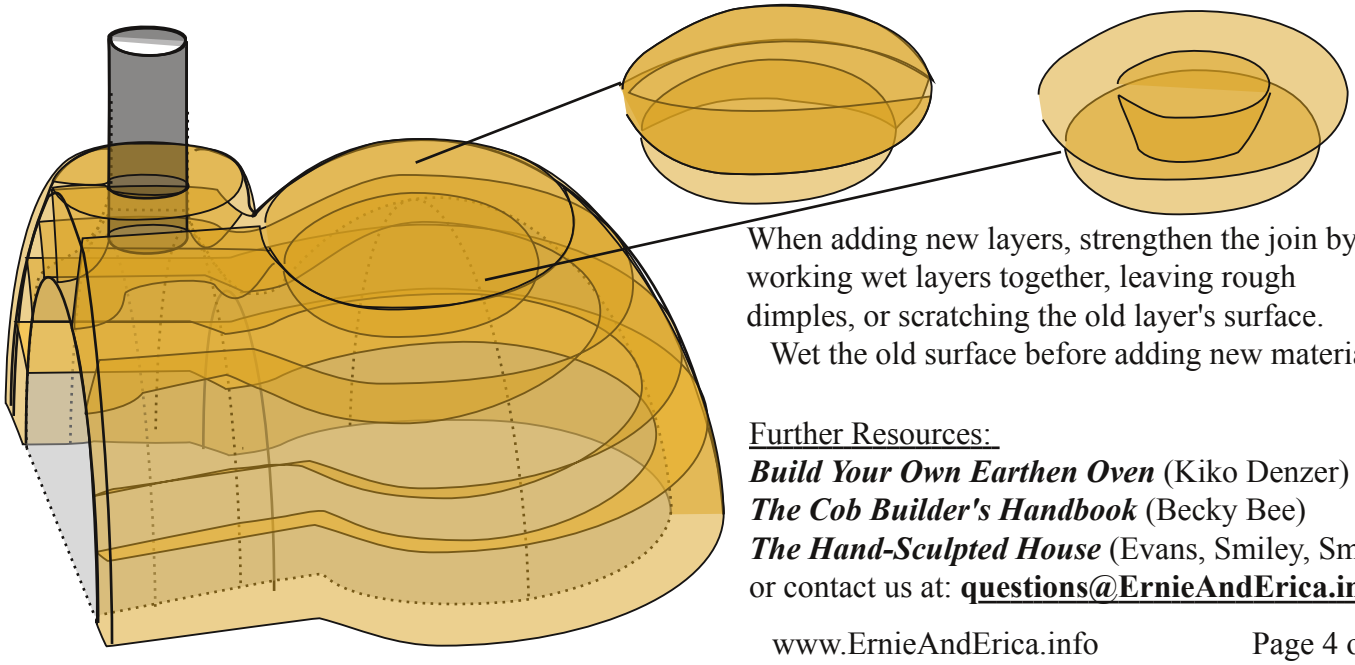
A Catenary Arch is the ideal shape for the curves of the sand mold. It helps the dome support its own weight.

Find this shape by holding a chain or cable in your two hands, the base distance apart. Let out enough chain to reach the planned height/depth. Have a friend trace the shape onto cardboard. Cut out the center, and use the outside to check your sand mold.

For more on catenary arches, see Wikipedia, or http://mathworld.wolfram.com/Catenary.html



Top 'keystone' options: long wedges, or round plug



When adding new layers, strengthen the join by working wet layers together, leaving rough dimples, or scratching the old layer's surface.

Wet the old surface before adding new material.

Further Resources:

Build Your Own Earthen Oven (Kiko Denzer)
The Cob Builder's Handbook (Becky Bee)
The Hand-Sculpted House (Evans, Smiley, Smith)
or contact us at: **questions@ErnieAndErica.info**

Earthen Oven Instructions

by Ernie and Erica Wisner
www.ErnieAndErica.info

Contents:

Introduction:

Building an earthen oven is an age-old traditional skill. We have described the basic principles and methods to help you build your first oven. As with any traditional skill, there is always room for practice and improvement. We encourage you to consider your own personal style, cultural expectations, and local surroundings while planning your oven. We have offered a few alternatives in some steps, where it seemed most useful, while keeping things simple for your first project. You are welcome to adapt these plans further to suit yourself.

Building with earth requires some experimentation with local soils and subsoils. Many people have heard of 'clay ovens' - but to believe that only clay is involved is similar to imagining that butter cookies are entirely made of butter, or concrete is entirely makde of cement. Good earthen masonry needs only a little clay as a binder; it is mostly aggregate (rough sand and/or straw). Too much clay will cause the material to shrink and crack as it dries.

We recommend making a few test batches, or a scale model, to test your local subsoils and practice your mixing technique. Look for hardness, strength, resistance to cracking, and minimal chipping or dusting-off. It's up to you whether to build your first oven as quickly as possible, to learn from experience; or take your time and practice each technique to better control the results. In either case, use your good sense and have fun. Nothing lasts forever, but earth is durable and forgiving.

Part 1: Preparations:

1) Design Considerations:

Our generic oven has enough room inside for a large pizza or several loaves of artisan bread. The chimney helps the oven burn more cleanly during the firing cycle, as well as carrying away the remaining smoke.

Earthen ovens take up a fair amount of space, not only for the oven and its heat, but also for the tools and workspace. Imagine a day's baking cycle, and design a convenient 'kitchen' for your oven.

Elements of an earth-oven bakery:

- Storage/shelves for firewood, matches/kindling, newspaper
- Flat places for trays / loaves / dough
- 2 Buckets: one for ashes & coals, one for water/tool soaking
- Hooks for firetools, peel (pizza paddle), gloves/hot-pads

- Heat protection for nearby surfaces / people, especially those facing the oven door
- Room to maneuver big pans and long-handled tools.
- Overhang to shelter the cook and food, as well as the oven
- Air flow for cooling / traffic flow for parties,
- Emergency fire suppression

Oven Shape:

Every regional village once had its own special oven shape to bake the local cuisine. Among dome ovens, pizza or flat-bread ovens tend to have a shallower lens, while multi-purpose ovens for raised bread and roasts are higher-arched. The dome focuses heat down into the food, against the sides, and onto the floor, to bake the lower crust with stored heat. Watch out for hot spots front and center in the dome!

This oven should be large enough to rotate your biggest pan inside the oven. If you want to bake with larger pans, or have a special purpose in mind, see the 'specialty oven designs' at the end of this document.

You may also want to make your plinth larger than shown. This allows room for thicker walls, and lets you create built-in work surfaces and storage.

In most climates, you need a roof over your oven, and well-drained supports underneath. In very dry climates, these are optional, but still handy for shade and sanitation. We have not shown the detail of these

structures, as they can be built various ways to suit local norms. Consider metal or tile roofing, and insulated chimney fittings.

Earthen ovens are traditionally built in an open kitchen or outbuilding, not inside a dwelling place. If you build inside an existing shelter, make sure the floor can support the weight (approx. 1 ton). Provide adequate ventilation (air for the fire, plus clearing of any smoke). Use a properly insulated through-roof chimney fitting, and heat shielding on any surfaces facing the open door, to protect your structure from the high temperatures involved.

We do not recommend building your first earthen oven indoors. If you do, please take extra precautions against smoke and carbon monoxide; accidental fires; and building damage from damp, weight, or heat.

2) Collect your materials:

Roof & Base (built to suit, using local methods; please do your own estimates):
- Drainage (gravel, about a yard or more; optional drain pipe to daylight);
- Roof structure (8'x8' or larger: footings, posts, beams, rafters/purlins, roofing, through-roof chimney fitting)
- Plinth (masonry or heavy-duty wood supports - about 30" tall, 60" by 60" square or slightly larger)

Oven & Sand Mold:
- Bricks - about 50 to make oven floor; plus extras as desired for temporary forms / steps

(10-25 for doorway arch(es); 20-30 for raising the floor above the insulation … extras (or rocks) to stuff under the sand mold and conserve cobbing sand … indefinite numbers for patio or garden features … Don't turn down any free bricks until you are done!)
- Smooth sand-mold liner (newspaper, 1-2 inch stack; *can substitute plastic wrap or sacks & duck tape*)
- Thermal lining mix (Fine sand, good clay slip)
    - About 6-10 buckets of sand sifted from pile, or 6-10 60-lb bags of masonry sand
    - About 2-3 buckets ceramic clay slip, or 2 50-lb bags powdered refractory clay / "fireclay"
- Insulation (perlite and clay) under floor and in dome:
    - 8 cubic feet of perlite plus
    - 1-2 buckets clay slip
- Outer cob mix (coarse sand, straw, clay)
    - About 2 yards of sand for sand mold plus outer cob layer. Toothy masonry sand, or 1/4"-minus rock-crusher or quarry fines.
    - 1/2 to 1 yard of clay soil, or 10 to 20 buckets ceramic clay slip, or 4 to 10 bags powdered clay (make test batches to determine proper mixing ratio for locally available types of clay)
    - 1 bale of straw (there will be some left over - 1/2 bale is usually more than enough.)
- Finish Plasters & Paints:
    - Fine fiber (horse dung or chopped straw - about 2 buckets);
    - 4 to 10 buckets of screened cob, leftover thermal lining mix,
      or lime-sand mortar/plaster base (3 sand: 1 part hydrated lime putty).
    - *optional: pigment, mica, wheat paste or plain yoghurt, lime (type S or slaked lime putty), borax*

- Stovepipe (and optional cardboard spacers) for chimney - enough to extend at least 2-3 feet above roof,
- sheet metal screws, wire, or flanged stoveipipe fitting
- Wood for oven doors - 15" by 20" slabs, handles (wood limb plus just-long-enough screws).

Alternative: sheet metal doors - make with scrap steel or stainless. If using insulation products, look for those rated for 1000 F for bake door, 1200 or 1800 F for burn door - you don't want binders off-gassing from wall insulation into food.

Dry firewood for test-fires; candle, fan, or lamp for slow-drying interior
Wood ash or waterglass for inner layer – a few cups

Fine sand for inner & outer finish layers (can buy bagged / masonry sand)

Tools: (some are *optional*)

Measuring & Marking:
Measuring tape or yardstick
Level (for leveling pad, drainage, and plinth)
Marker (chalk, permanent marker, dark pencil, etc)
Square
Large paper template / blown-up plan drawings
Skinny sticks (e.g. chopsticks or Popsicle sticks) for making thickness probes
Chain or cable to visualize catenary arch; cardboard to mark and transfer this shape
String to mark out circles / lengths; plumb line

Mixing cob:
Tarp(s) (8' x 10')
Shovels (2)
Buckets (3 to 8, plus bins or small tarps for staging loads)
Water faucet, hose
Wheelbarrow(s)
Boots, gloves
Heavy-duty paint stirrer or mixer attachment for drill, for making clay into slip
Screens (¼" mesh or window screen, to strain rough materials for fine plasters;
½" or bigger mesh for grating dry clay / screening out broken junk from urban sources)

Applying & trimming cob:
Hands, small sticks for poking
Stepladder / sturdy stand-on stuff (for working up high).
Paintbrushes / sponges / small dishes / spray bottles (for wetting and joining dried layers of cob, and for finishes)
Masonry tool(s) for inner and outer fine plasters: *(can substitute yogurt lids / scrap wood or metal)*
trowels, floats, corner tools, water container for dipping them into;
Bricks or small boards for temporary formwork if desired
Torch or flamethrower for singeing away straw 'whiskers' before final plastering

Brickwork:
Rubber mallet / block of wood for tapping to level *(Level already listed above)*
Sand and brush/broom head (can also be used to apply slip, and clean tarps/wheelbarrows)
brick-sets / masonry blade, if planning to trim any bricks

General tools:
Pocket knife for opening bags/boxes
Duck tape
Tin snips or hacksaw; short sheet-metal screws & driver (metal/stovepipe work)
General building tools (hammer/nails or driver/screws, crowbar, shims, etc)
Power tools
small saw or grinder (metal cutting / making roof or forms)
power drill (for paint stirring / making forms / stovepipe screws)

3) Mark the placement of your oven.

Draw the oven's footprint at full scale, on a large piece of cardboard or butcher paper. Leave a few extra inches on the sides in case your walls get thicker during the building process. Move it around in your building space. Line up the chimney-holes in the oven and roof. Avoid putting the chimney through a roof supports. Allow plenty of room for your plinth, supports, and other features.

Tips and tricks: Instead of trying to mark your diggings with stakes underfoot, you can 'draw' your building footprint with long strings. Drive tall stakes into the ground outside the work area, aligned so that strings tied between them will cross at the key features like the corners of the plinth. Disconnect the strings while working, and re-check as needed. You can mark the future floor level, or plinth level, on the stakes too.

Drop a vertical from your chimney's hole-in-the-roof using a laser level, plumbline, or rock on a string.

4) Establish drainage.

Drains should run from dripline of roof, downhill to daylight (a point where the natural slope of the ground exposes the drain pipe). A French drain works well: 12-24" deep sloped ditch, perforated pipe at the bottom, backfilled with gravel and compacted level. A sloped pan under the entire plinth, filled with compacted gravel, will help drain any unwelcome moisture into your drainage trenches and away from oven.

Your foundation or compacted gravel under plinth should go below your frost depth, and spread the weight of the oven to avoid crushed drainpipe or uneven settling. If your plinth will be a table on stout legs, consider spreading the weight with piers or pavers under each leg.

Use your shovel flat along the bottom of the trench, to avoid digging too deep and creating non-draining pockets. When filling back in with gravel, consider leaving space for pavers or boards underfoot.

5) Test your materials.

The subsoil from the drainage excavation may be great for cob. As you dig, separate the soil onto two piles or tarps. Set the dark topsoil aside for your garden. Use the deeper subsoil (generally lighter in color) to make a few test-batches of cob (see part 2, section 10, for detail on making cob). Set the test bricks aside to dry, or speed-dry in an oven.

6) Roof:

We prefer to build the roof before the oven. This shelters the remaining work, and holds the chimney in place during the delicate sand mold removal. If you need to build the oven first, plan where the roof supports will go before building your drainage and plinth.

Make the roof large enough to cover the baker, tools, and dry firewood storage as well as the oven itself - e.g. a shed roof with big overhangs.

Allow clearance for working under the roof with long tools, and for getting at the top of the oven in case repairs are needed. For heat safety, we'd suggest 18" to 36" above the oven (depending on your roof material, slope, and the insulation of your oven).

Some outdoor ovens have a tile or metal roof supported right off the oven itself. It's hard to get really good rain protection this way, and even 'turtle' roofts need ventilation so the roof doesn't trap damp against the clay, but it can be done.

Look at other local outbuildings for clues to appropriate methods and materials (to deal with high winds, driving rain, earthquakes, etc.) Consider chimney flashing and sealing, and less-flammable materials.

A tidy roof on Wendy and Patrick's oven (photo courtesy Patrick at Thirteen Vegetables Blog: http://thirteenvegetables.wordpress.com/2012/07/10/cob-oven-lessons)

7) Plinth: Create a strong base for your oven, with its top about 5 inches below your desired oven floor, and as level as possible.

The plinth in our drawing was made of 'urbanite' (reclaimed sidewalk

slabs). We stacked it in flat courses and use a lime-sand mortar to fill any gaps. You could also use cinderblock with rebar and cement mortar, or fieldstone, or brick. Note: Neither lime nor cement should be used near hot areas of the oven.

As an alternative, you may use 4"x4" or larger lumber to make a sturdy table. Line the table with tile and/or foil before starting the oven insulation. Use 1" extra floor insulation, with no heat-bridges.

Mark the placement of the oven by tracing the inside and outside of the walls on the plinth. Check that the chimney lines up correctly with the hole in the roof.

Part 2: Building the Oven

1) Mix the floor insulation:

We combine one bag (2 cubic foot) of perlite with about 1/2 gallon of thick clay slip, to create a stabilized insulation mixture with about the consistency of hot caramel corn. Perlite is a fine 'glass foam' produced from volcanic rock. Wear a dust mask or dampen the material before working, as the dust is fine shards of volcanic glass that can damage lungs.

Insulation Alternatives:

If your budget allows, insulative 'kiln brick,' or board-type ceramic fiber insulation, are pre-formed in uniform thickness, and highly effective. Both can be purchased from industrial ceramics suppliers. Instead of 2" of perlite, you can use 1" of pre-formed industrial insulation.

Some people like to make their own 'ceramic foam' insulation with sawdust and local clay soils. We have not been satisfied with the results on this material; it tends to crumble over time. Please experiment before using this material under the oven floor.

2) Build a rim where the oven wall will go. Use rough cob, or mortared brick (2 bricks thick to support the 6" oven wall).

3) Lay insulation inside the rim: pour in the perlite mixture, use a board to spread it evenly to fill the entire oven floor area, then press it down into a flat layer of perlite about 2" thick.

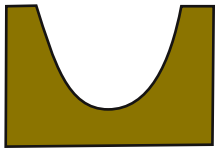
Be sure to create even support for the brick floor. If your plinth is non-combustible, you can place 'spacers' (small, even pieces of brick or tile) under every seam in the bricks. Or just compact the perlite down evenly, so it will not crush further, and level the space.

4) Place the floor bricks on top of the insulation. Tap down gently to level the bricks, and ensure that no loose edges will stick up. Remember you will be removing ashes with a hoe or rake, so any proud corners will become loose bricks over time.

When you are happy with the placement and level of your bricks, sprinkle on fine sand, and brush it between the bricks to hold them in place. Mark the oven's outline on the bricks, both inside and outside walls.

5) Build the sand mold.

Create a mold for the oven's interior (the future 'air space' inside the oven) with damp sand. Stay inside the tracing of the oven's inside walls. You can use a few bricks or small rubble pieces to build up the center quickly, but stop a few inches away from the inside walls. Define the dome itself with smooth, wet sand.



The dome is shaped like a catenary arch (the same shape as a hanging chain, but upside-down) to support its

own weight. You can use a chain
or cable to create any width and height of catenary arch shape you want. Trace them onto cardboard templates to check the cross-sections of the dome.

The smoke chamber is also a catenary arch – actually, two of them, with a dome-like vault in between that supports the chimney. Each doorway will need to be 3-4" thick for good arch strength.

Place the **chimney pipe** on top of the smoke-chamber mold. If necessary, you can use a temporary spacer, and mount the actual stoveipipe later. Use a 6" ID cardboard tube so that the actual hole is slightly more than 6" around.

If you place the actual stovepipe now, set it at the very top of the sand mold, with the crimped end down, (so that any condensation will run tidily inward).

Make a thin layer of cardboard, newspaper, or lining material around the chimney metal, to serve as an expansion joint. 1/8" on all sides is plenty.

Make sure the chimney has some protruding tabs or flanges about 4" up from the sand mold, to support it on the earthworks once the mold is removed. You can drill some sheet metal screws in from the inside out; use a ceiling or wall escutcheon, or an old woodstove collar, that was designed for the job; or wrap some wire through holes in the metal to wire it in place.

Be sure there is enough space left on your plinth for the full thickness of your oven walls. If necessary, reduce the size of your sand mold to allow enough space for the oven walls.

When you are happy with the shape, press it firm with a steel float or wooden board. Wrap the sand mold in paper-mache (strips of wet newspaper) to make an absolutely smooth shell for the interior of the oven. Trim the bottom edges so the wrapper does not create any gaps between the oven walls and brick floor. Paint the surface with clay slip.

(We prefer the paper wrapper because you can burn it out instead of removing it. You don't want to pull anything loose from the oven itself when you remove the sand mold.

If you want to make a plastic liner with bags or plastic wrap, tape any creases smooth, and carefully remove the liner when you remove the sand mold.)

6) Mix fine 'thermal plaster' for the oven lining.

This is the most critical material, as it must not crack or drop grit in your food, even under intense heat. This interior lining should go on in one work-day, to form a single, strong layer. Make a few test batches and dry samples ahead of time, to ensure that your mix can dry without cracking. Traditional earthen plasters rely on straw or organic fibers to prevent cracking, but the high temperatures inside the oven will completely burn away any organic material. The good news is, the heat will also partially vitrify (harden) the lining, making it more durable over time. Test-dry samples quickly in another oven, on low heat, to save time.

We use a ratio of **3 to 5 parts fine masonry sand** (sharp grains, sifted through window screen), to **1 part clay slip** (a thick smooth putty or creamy liquid, made by wetting powdered fireclay, or sifted ceramic clay). Proportions may vary for local materials. Sometimes we include a very small amount of wood ash, or waterglass, to help glaze the lining when the oven is fired.

Mix thoroughly, until the lining material forms a thick paste that can support its own weight. The texture will be like moist brownies or stiff cookie dough. Allow excess moisture to dry out if needed, before shaping the oven. (See below for more detail on the cob-mixing process.)

7) Shape the inner dome: Make sure you have time to finish this layer in one work session.

Your sand mold defines the interior shape of the oven. Your main job with this next layer is to press the material evenly around the mold, to create a smooth, solid lining about 2" thick. Smooth and smear the material alongside the mold, so there are no voids or bumps.

Build your first course as a ring along the base of the mold. The top of the ring should be level all the way around, and slightly tilted inward, as if you were building an igloo. Build the next ring on top of this, and so on, until you are near the top of the oven.

At the top, you can either continue like an igloo (smaller and smaller rings, and then a roundish plug), or switch to long wedges like orange segments. (Like a stretched-out stone arch, with a long thin keystone.) We prefer the orange wedges, as it is easier to check the thickness.

Shown: Inner dome complete, and insulation layer starting (bricks are bracing wet material to keep it from slumping until it dries a bit).

Keep thinking of igloos and arches as you build.These 'keystone' shapes help the dome resist movement, even if hairline cracks occur at the joins.

If you think the dome is slumping as you build, allow the first rings to dry slightly before continuing. To check thickness, you can carefully poke in a blunt toothpick or chopstick in until you reach the mold wrapper.

Alternative lining materials: A slight improvement might be made by using ceramic grog or sifted rock-crusher fines in place of sand. Some commercial ovens use firebrick, cut into keyed shapes, to make a self-supporting dome or vaulted tunnel. This requires more tools and time, and may give a slightly less even heat, but allows the oven to be taken apart and re-assembled. A broken earthen oven is simply re-made.

Portland cement should not be used in food ovens. Most dome ovens bake above 500 F - up to 800 or 900 F for thin-crust pizza. The pre-firing often bakes the clay into soft brick (1900 to 2200F). At these heats, Portland cement breaks down into its component chemicals, and then drops cement-powder residue in the food. Some refractory cements can take these heats. Check temperature ratings and food-safe suitability.

8) Mix more insulation for the oven walls. See step 1 for proportions of perlite and clay. You will need at least 2-3 batches for this layer.

Alternative Dome Insulation: Some traditional ovens are built only of straw and clay. If perlite is hard to find, you can substitute a double or triple thickness of straw-clay for a somewhat-insulated dome.

Mix clay or subsoil 'slip,' and wet the straw in it; add a little sand to make a very straw-rich cob. (Just enough mineral soil to hold the dome in place when the straw burns out). You can build the straw dome in 2-3 layers, with a thin seal of clay between each layer, for a better smoke-seal.

We prefer the perlite-clay insulation mix over straw, because it takes less material, lasts longer, and performs more consistently over time.

9) Build up the insulation dome in the same way as the previous layer, in 'igloo rings'. We make our perlite insulation at least 2" thick. If you have enough perlite and room on your plinth, you can make this

layer 3" or 4" thick or more.

As you form the rings of the igloo, you want it to join snugly with the inner layer. Scratch the old surface gently to create places where the new layer can grip. If the inner layer is dry, dampen it with water as you work, or brush on a little clay slip. Wet joins bond better.

If your perlite is too wet, or too dry, it will be difficult to form. You can use bricks to create temporary supports beside this layer until it dries; and you can adjust the amount of water or clay. There should be enough clay in the perlite for it to hold its own shape as it dries.

Drying time: In our rainy climate, we often stop at this point to allow the inner layers to dry for a day or so. If your layers are firming up as fast as you can build them, you can keep building.

10) Mix cob, and build the cob layer the same way.

'Cob' is a wet-formed earthen masonry material, similar to adobe or rammed-earth. The word itself means 'loaf' or 'lump.'

What is cob? **Cob is not just clay.** Archaeological analysis shows that historic 'cob' is usually between 6%-30% clay, 30-70% sand, with the remainder a combination of aggregates or other matter such as straw, chalk or lime, gravel, silt, etc. Traditional cob was made with local subsoils, and local building standards set the wall thickness to suit local conditions. Modern (Oregon) cob involves mixing 'recipes' that use local soils where suitable, but amend with off-site materials to perform like an ideal sculptural material.

In any case, only the mineral subsoil should be used. Set aside any dark, rich topsoil for your garden.

Cob mixes vary by region. In western Oregon we have clay-rich sub-soils, so we add 3 parts masonry sand to 1 or 2 parts clay soil, mix this with a little water, and then add 1-2 parts straw (by volume). In high deserts (Arizona, New Mexico), you may find ready-mix soils, just add water and straw. For sandy soils, you may wish to add only a little ceramic clay. Silty soil is not ideal for building cob; it remains soft and crumbly. (Good for gardens, bad for buildings.) Look for 'free fill dirt' from nearby with more clay, sand, or gravel.

Make a few test batches, and make little test bricks to dry ahead of time, to check for cracking or crumbling as the cob dries out. You can bake a test brick in your kitchen oven to dry it faster if needed.

Mix each batch thoroughly. We stomp it on a tarp, then roll the tarp to turn the mix, and squash the cob out again, until no further change occurs from working the material. You can also work it in a wheelbarrow like wet mortar mix, then let it dry to a firm paste before building.

We typically mix a 4- to 6-bucket batch of cob on a tarp, and this oven takes roughly 5-6 batches at minimal thickness. Note that the batch volume will typically be the same as the volume of aggregate alone - the clay fits in the air pockets, so 3 sand plus 1 clay makes 3 buckets of cob. 20 to 30 buckets of cob means about a yard of sand. (Plus another yard for the mold). It pays to get extra material just in case, as most dump trucks charge more per visit than per yard.

Testing the cob: Shape the cob into a ball and drop it from about shoulder height (4 feet). The ball should remain intact - no crumbling. Next, smear the cob onto your open hand and work it between your fingers. It should stick well enough that you can turn your hand over, and even wiggle your fingers a few times, without the cob falling off. And of course, it should hold up its own weight: can you stand on it and get taller?

The final test is a subtle one: squeeze the ball in your hand and listen. You should hear sand grains

grinding together, and the material should not ooze water or clay out through your fingers. If clay oozes out, add more sand or straw to take up the excess clay. If water oozes out, your 'clay' was really silt; find some real clay (dig deeper or find a pond), or get some ceramic clay scraps or powdered fireclay if needed. About 3 50-lb bags of powdered fireclay is enough for one oven; using local dirt as well, you should only need a gallon or two of ceramic clay slip for each batch (4- 6 buckets) of cob.

The inner dome has no straw, so extra sand may be needed for stiffness. The outer dome should have as much long straw as you can shove into the mix, well integrated and coated with mud. The straw will take up some of the water, so you may need to add water or clay slip as you mix the straw in.

With your first batch, shape some large sample bricks, about the same thickness as your oven walls. You can speed-dry samples in an electric oven at any temperature up to 'broil'. When the cob is completely dry, it should no longer feel cool to the touch. Check for cracks, crumbling, or uneven mixing.

When your cob is satisfactory, **build the dome layer, 2" thick** or thicker, around the entire oven. Work the dome as before, as an igloo. Work carefully and firmly to create good joins without distorting the layers underneath.

Good cob technique: support the sides, while pressing new material *downward*. Push with fingers or a small stick to 'sew' the straw into the previous course. **Don't 'pat' cob into place,** nor try to push slumping material back up. The cob will only slump further when released. Patting and pushing up creates hidden weak spots where the material can separate. Instead, work with firm movements so you can hear the sand grating. If material slumps, let the bulge dry until firm, trim off any excess, and mix the trimmings into the next batch for re-use.

Even if you want to create fanciful shapes, **build this first layer of cob to an even thickness**. Let it dry, patch any cracks, and then add new layers to build up sculptural details. An uneven layer of cob will dry unevenly, and thin areas will crack. See steps 13-14 for more ideas about decorating the oven.

11) Allow the oven to dry. This may take up to a week.

If any cracks appear on the outside, let the oven finish drying completely, and then cut back the cracks to make sure they are only in the surface layer. Surface cracks can be patched. Moisten the trimmed edges, and fill with up to 1" of new material. Cracks over ½" wide may indicate serious problems with the cob mix. Cracks can be caused by too much clay in the mix, by not mixing the batch thoroughly, or by applying the cob unevenly.

12) Remove the sand mold. Carefully scrape away a few inches of the sand, and check the first arch. Is the cob dry enough to support its own weight? It should be at least leather-hard. If not, stop and let the first arch dry before moving any more sand.

When the cob is dry enough, remove more sand. Gently work back, checking each section, until the entire dome has been cleared. (If you used a plastic wrapper on the sand mold, carefully work it free without detaching any of the oven lining.)

Check the interior of the dome for cracks or loose rock. The interior of the oven is difficult to patch, and can drop grit into the food. You can use wet fingertips to gently smooth out small irregularities, and check for deeper cracks. If any large cracks or broken areas appear inside the top of the oven dome, we recommend starting over and re-building the oven from the floor up. Unfired materials can be re-mixed and re-used, but look for more / better aggregate (very sharp sand, or fireclay grog) to prevent cracking the second time. If there is no sand in your area, you can go ahead and fire the oven a few times, then break it apart

and re-mix and re-build with the same material. The partially fired clay will serve as grog for the next version, reducing shrinkage cracks. You can also make partially-fired clay bricks or straw-clay crumbles in a bonfire, and crush them down for grog.

If there are no cracks, allow the oven to dry firm before firing. (Some builders light a small test-fire, or put a fan inside the oven, to help with drying. The picture shows a work light bulb we used to gently speed dryng. Do not burn a full-scale fire until the oven is completely dry.)

When you first build a fire in the oven, be extra careful to avoid bumping the inside of the oven with the firewood. Watch for smoke leaks (steam is normal and OK, but smoke should only escape out the chimney). The full-scale firings will help harden the interior lining of the oven, making it somewhat tougher.

13) Sculptural plaster: Sculptural effects, mosaic tile work, or other decorative finishes may be added after the cob shell is mostly dry. The diagram shows a smooth dome, the simplest shape. But many people like a whimsical oven shape. Gentle curves and relatively even thicknesses are strongest.

A great variety of earthen plasters are available, as well as lime or gypsum plasters.

A simple **earthen plaster** can be made in the same way as cob, but with fine-chopped and sifted ingredients: 3-4 parts sifted sand, 1-2 parts sifted clay, 1 part chopped straw or fiber (horse dung, hair).

A basic **lime plaster** can be made with 1 part lime putty, 2 to 4 parts fine sand, and 1-2 parts fine fiber (animal hair, chopped rope, etc). (Use fresh type S lime, or look for hydrated lime putty.) Paint- or concrete-pigments can be added for color.

Scratch the surface before adding fresh plasters, to 'key in' your new layer. Key and patch any surface cracks. Moisten the surface with a spray-bottle or paintbrush, then add plaster in firm, smooth strokes. Build up shapes a little at a time, so that layers do not become too heavy and crack or fall.

There is literally no limit to the colors that can be obtained from non-toxic natural pigments. We went a little crazy on the frog in this earthen paints class.

Shown are yellow aliz, red and dark blue egg tempera, red and green clay paints, and light blue lime-milk paint.

14) Paint or tile: Many kinds of natural, breathable finishes can be used to beautify your oven.

We do not recommend synthetic materials such as latex or acrylic paint over earthen ovens:

1) They are not heat-tolerant, and more importantly,

2) They can seal in moisture (steam) that will weaken the earthen oven over time.

This problem has been observed with 'waterproof' modern materials including cement-based stuccos and mortars; latex, vinyl, or cement-based tile grouts; and 'waterproof' surface coatings and paints. The moisture trapped by such materials causes earthen structures to collapse. We do not recommend any of the above materials for earthen ovens.

We do recommend earthen materials and other natural, breathable paints and putties. Lime mortars, lime plasters, and lime-sand tile grouts can be used; as can clay-based mortars, plasters, and paints.

A **simple clay paint** can be made with 1 part clay to 1 part pigment or mica. For a harder finish, you may include a small amount (up to 2%) of extra binder like egg yolk, wheat paste, yogurt, or linseed oil; be aware that these ingredients can mildew.

A simple **lime-milk paint** can be made with 1 part plain yogurt, 2 parts lime putty, and 2 parts pigment (if you want a lighter shade, substitute some chalk, talc powder, or mica for all or part of the pigment). Concrete pigments work great with lime and clay coatings, and are readily available in most areas.

To prevent cracking or peeling of paints, we recommend that home-made paints include a non-shrinking extender (pigment, mica, or chalk). Clay is prone to shrinking as it dries. Do not pre-wet the cob surface, but **dilute the paint with water** so that it soaks in rather than forming a separate layer. Whitewash or lime-wash can also be used as paints, to brighten and harden the oven's outer surface.

Mosaic tiles can be set directly into fresh cob, top-grouted with natural lime-sand putty, or set into a fresh layer of lime-sand or clay-sand mortar. Only the joints will 'breathe,' so we prefer smaller tiles with more joints, or broad areas of breathable plaster between mosaic details.

Fresco painting can be done on fresh, soft plaster with any natural paint; the traditional indoor frescos are egg tempera on lime plasters. The paintbrush gently shapes the wet plaster while painting, for fun 3-D effects. Painting on dry plaster is called **secco painting**. Paints bond best into lime plaster in the first 3 days.

A degree of water-resistance can be achieved with lime, milk paints, diluted linseed oil, or rain tiles. Avoid trapping interior moisture. The main water protection should be the roof, with an air gap above the oven, so the oven itself can dry out.

Many people like to re-plaster or re-paint their oven after a few years, to enjoy fresh decorations.

15) Oven Doors:

You will need two doors for this type of oven: a larger 'Burn door' for the outer doorway, and a smaller 'Bake door' for the inner opening.

The burn door covers the outer opening during firing. It can be wood, metal, or a composite with insulation. It should have an air gap at the bottom, roughly the same size as the chimney opening. (Our diagrams show a 6" diameter chimney, which has a 28-square-inch cross-sectional area; the slot in our metal burn door is about 2" by 14". 3" by 9" would also work fine.)

The bake door is used to plug the inner door, during baking only. It can be made of wood, or any suitable material. It should fit the bake doorway like a plug, with no major air gaps: tapered inward, so it fits snug but can be removed easily.

Provide a good, big handle on both doors for easy removal - you may be opening the door with a firetool and/or wearing heavy welding gloves.

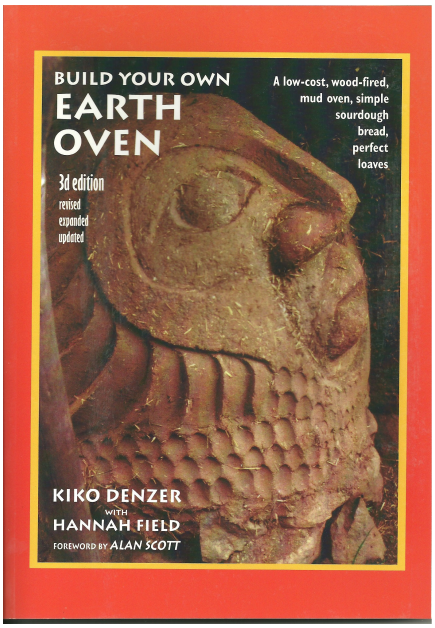
Don't wood doors burn up? Traditional oven doors are made of wood. The door is soaked in a bucket of water before baking each batch. The door will slowly char with repeated use. The doors start out 2-3 inches thick, and are used until one part chars down to less than an inch (1/2 inch in some cases). The door is replaced as needed. A nice-smelling wood like alder or fruit wood can give a pleasant flavor to the oven; dipping the door in water helps add steam in the oven for artisan bread crusts, and makes the door last longer. And frankly, it's kind of tidy and satisfying to use local materials, and be able to burn your old door as fuel after you replace it. Often, the handle can be transferred to the new door.

Modern oven doors can be metal, high-temperature insulation, or even fancy layered mica. These materials are more expensive and harder to repair, but can create a durable door that will out-last many ovens. Fit your new oven to an existing door by placing the door in the sand mold - plus a thin layer of crushable material such as rock wool. The earthen ovens do shrink slightly as they dry. If necessary, sculpt the doorway a little more after removing the sand mold.

Some people like to line their wood or insulative ceramic-fiber-board door with reflective foil or sheet metal. Be wary: firing temperatures can melt aluminum, and cause sheet metal to expand and chip away the masonry. Disposable foil liners can last for several firings and help protect the door. We recommend using food-safe materials for the bake door, as residues may get in the food.

I've even seen sculpted clay doors, sometimes with firebrick liners. These are delicate and can get hot, but

can be very beautiful.



16) Chimney Fitting:

The chimney serves not only to raise the smoke away from the cook, but to preserve outdoor air quality by promoting a cleaner, more efficient burn inside the oven itself. A spark-arresting cap helps prevent wildfires.

We find that 2-4 feet of chimney allows plenty of draft for the stove, but more may be needed to carry the smoke above nearby structures.

Follow local building code guidelines for safe chimney installation. For example, raise the outlet of your chimney 2 feet above any structure within 10 horizontal feet. This gets the smoke up where the wind can carry it away, instead of blowing it back down. To put the chimney through a wooden or wood-supported roof, use proper fittings like triple-wall stovepipe with insulation or air gaps.

Further Resources:

We highly recommend Kiko Denzer's book, ***Build Your Own Earthen Oven***. Although he does not include ovens with chimneys, there is a great deal of good information about cob, baking technique, and artisan bread recipes. Available from Handprint Press, www.handprintpress.org.

There's nothing like experience to help you turn local soils into good cob every time. If you can't go to a local cob building project and get your hands dirty, the next best thing is to read up and practice. (Make little scale models, fairy houses, or adobe bricks.) For a wealth of detail from three masters of the art, try ***The Hand-Sculpted House*** by Ianto Evans, Linda Smiley, and Michael Smith. If you need a briefer reference, try Becky Bee's ***The Cob Builder's Handbook***. (Both from Chelsea Green publishers, or contact the authors directly - www.cobcottage.com).

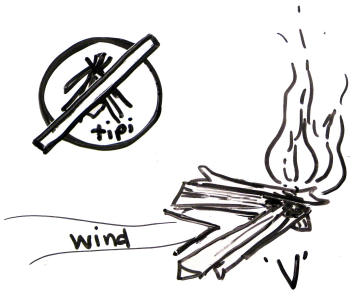
For online information about detailing earthen building, and especially for weather-protection and ground-damp in maritime or rainy climates, we like Graeme North's white papers from New Zealand:
www.ecodesign.co.nz
and Mike Wye's natural building articles and FAQ's from Devon, England: www.mikewye.co.uk/

There are many online discussions of earthen building available; and lots of good information about other traditional oven shapes like the Tandoor, Beavertail, etc. I've seen several basic plans for traditional ovens available freely on the Web.
Among other places, there are good articles at www.HandprintPress.org
and great discussion forums at www.permies.com.

Part 3: Operating Your Earthen Oven:

Each earthen oven has its own unique character. With practice and attention, you will learn the quirks of your stove, and cook beautiful artisan foods every time. We recommend keeping a notebook for the first year to record you favorite recipes, baking times, temperatures, and other useful observations. (Note your cob and plaster recipes too!) The following should help you get started:

1) Firing:



- About 4 hours before bake time, build a small fire to start the oven drafting. We like the 'V' shaped fire with the point toward the back, because it's easy to light it under the chimney and then move it further back into the oven whenever you like. (The unburned ends of all the sticks are on your side of the fire).

When the fire is going strong, fill the oven with wood and close the 'burn door.' **Be careful - don't damage the oven lining with the firewood.**

- Prepare your dough and other foods for baking. Almost any good bread recipe will work well; and I've had remarkable results with other baked goods like biscuits and scones.
- Allow the fire to burn down to coals (2-4 hours).
- Start soaking peel and/or wooden doors in a bucket of water.
- Set the burn door aside.
- Scrape the coals and ashes out (using a sawed-off hoe or fireplace shovel) into a metal bucket.
- Swab oven floor with damp cloth if desired (only needed when baking directly on bricks); avoid touching walls with damp swab.
- Close the bake door and allow the oven to 'mellow' for 5-10 minutes while you get the hottest-baking foods ready. (Mellowing brings the oven floor up to the same temperature as the roof and walls.)

2) Baking:

- Check the temperature near the mouth of the oven with your oven thermometer. Remember, inner temperatures may be much hotter – do not reach inside.

You can also throw a handful of corn meal or coarse flour on the oven's floor to see whether it burns, chars, or browns. If it bursts into little glowing embers immediately, the oven is probably too hot for anything but searing. We like to cook our thin-crust pizza when corn meal browns in about a second.

- Load your hottest-cooking foods first.
- Close bake door while baking.
- Check halfway through the bake time, and rotate food for even browning if needed.
- Remove food with peel or tongs - do not place hands in oven!
- Check temperature again, and load second batch of food. Later batches may take slightly longer to cook. Repeat as desired until oven cools below working temperatures, or baking is done.
- Let foods stand before serving if needed.

3) Maintenance: Very little maintenance is required, beyond keeping the oven dry. Fix any leaks in the roof right away – heat and moisture can do a lot of damage in a hurry.

Cleaning the oven is not necessary, beyond scraping out the ashes after firing. The high-temperature fire destroys any germs along with any other organic matter. Do not use the oven for non-food purposes like ceramics (except maybe non-toxic experiments with plain, unglazed clay - even then, I'd use a kiln shelf to avoid baking bumps into the oven floor).

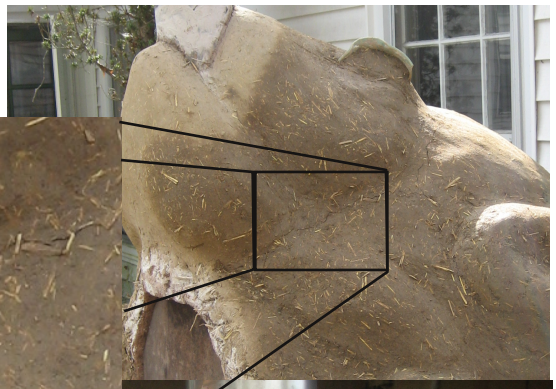
Never use chemical oven cleansers, they're toxic and unnecessary, and could permanently contaminate the porous surfaces of the oven.

Keep the door in place when the oven is not in use, to discourage nesting animals.

If the oven does get spills or soils on its outer surfaces (e.g. birds nest above it or something), you can wipe down the surface with soap and water. Another traditional remedy is to re-paint with lime wash; lime's alkalinity can help neutralize many offensive materials. If necessary, you can scrub down into the plaster to remove a noxious problem like pet urine, and re-coat with fresh plaster or paints.

Doors may need to be replaced occasionally, depending on materials and firing temperatures.

Periodically inspect the oven, inside and out, for cracks or settling. Small cracks can be patched, and loose bricks can sometimes be re-set by vacuuming out and then brushing in a little more sand. Surface wear-and-tear can be repaired with a fresh coat of earthen plaster or lime plaster, or simply painted over. This includes nicks or scratches in the archways (from banging pans or tools); patch with the same heat-tolerant plaster as you used for the interior of the dome.



Sometimes large cracks may appear in the front of the oven, or between sculptural details. If cracks get larger while firing, they are due to thermal expansion. Make sure the oven stays dry between firings (steam from trapped moisture can do a lot of damage in a hurry, and cracks can let moisture in and steam out).

Inspect the oven to see how deep the crack goes. If it's only in one or two layers, you can try patching it with a dense clay-sand plaster while the oven is warm, to stabilize it at the larger size (creating an expansion joint retroactively). A crack in the front doorway of the oven is not as critical as one in the dome itself, and easier to patch.

If any large cracks

appear in the top of the dome, on the inside, the oven's working life is over. Loose material from the cracks has begun trickling into the food, dropping grit and unpleasantness in the soft cheese of your pizza pleasures. Return your oven to the earth, and re-build. All oven materials can be added to garden soils, including the charcoal and ash; and most of the oven materials can also be re-used in building your next oven. Strip the oven down to the brick floor, re-level on fresh sand or insulation if needed, and re-build.

Traditional ovens may last between 2 years (unsheltered or tarp-covered oven, clay ovens without enough sand) up to 20 years or more for a well-protected and well-built oven.

About earthen ovens:

Pre-heating / 'Soaking' the oven with fire:

Most earthen ovens do not bake directly with fire, but use stored heat from the masonry walls. This gives a more even temperature than is possible in other types of ovens, and browns the food from all directions at once. Pre-firing usually takes several hours, and the heat is then available for baking for about the same length of time, determined by the oven's design.

Traditional recipes never 'turn up' the heat once baking has begun. Experienced bakers often prepare several courses to go into the oven in sequence, starting with hot-fired pizzas or broiler foods, then breads, roasts, cookies and cakes, biscuits or scones, casseroles or roasted veggies, and finally slow-cooking puddings, dried foods, or yogurt/yeast cultures for the next days' meals.

You can extend the firing cycle slightly by leaving a few burning coals along the sides of the oven, but you will not re-create the intense heat provided by a full oven firing cycle. Leaving coals in the oven can add a lovely smoky flavor to foods.

You can re-warm the oven with a second fire between baking cycles. Use smaller wood, as the second fire will not need to burn as long as the first one. You can also try building a very small, bright fire in the back to 'flame-broil' certain foods. The flames will lick across the top and down into the doorway of the oven, as fresh air flows along the bottom past the food. Practice this in casual company before trying in front of guests!

Cooking Temperatures:

Earthen ovens can bake substantially hotter than electric ovens - up to 800 degrees Fahrenheit or more! These heats allow quick-cooking pizza and other delicacies for textures that are not possible in a modern oven. For temperatures over 500 degrees, cooking time is measured in minutes - e.g. 4 minutes for a thin-crust pizza.

The other thing to get used to is the time curve. While an electic oven can be set to a particular temperatuer for hours (and varies up and down by tens of degrees during that time), an earthen oven is fired very hot and then slowly cools. It starts out at 1200 to 2200 F during the hottest part of the firing. After the coals are removed and the oven 'soaks' some heat into the floor, it may be down to 900 F or so. If the bake door is kept in place between batches, you may get four or more hours of useful baking time.

Each batch of the same type of food may need to be cooked for a slightly longer time as the oven cools. An oven thermometer will help you judge the cooking temperature. Don't leave it in the oven all the time, but use it to check temperatures near the mouth of the oven before each batch. Remember that the radiant heat in the center is more intense. The thermometer is merely a guide, to help you learn how long to cook foods in your particular oven during the different stages of its slowly cooling bake cycle.

Please be careful with your new oven. You are literally playing with fire. Keep an eye on the oven at all times while it is hot. Warn others not to put hands inside. (The radiant heat from the walls focuses at the middle of the oven, and can cause severe burns.) All parts of the oven may be hot, and will remain hot for a long time after the fire is gone. Be alert and avoid accidents.

Efficiency vs Convenience:

Earthen ovens take a great deal of wood to heat, but can cook an enormous amount of food if the entire baking cycle is used. They are not very efficient for cooking a single meal; much of the heat is wasted in the

long heat-up and cool-down periods.

Many traditional cultures do not build separate ovens for each family, but share one large oven per village. In a community setting, the oven can work all day, using less fuel per meal. Baking may be done by one paid baker, or cooperatively among 'shareholders'. Ovens that are used daily take much less wood to fire than an occasional-use oven, because the stored heat from previous cycles is not wasted.

Our generic oven is based on the work of Kiko Denzer, Cob Cottage Company, and other members of the 'Cob Revival.' It is large enough to share, but not too large for the single-home baker. The size, thermal mass, and insulation are designed for a moderate baking cycle of about 4 hours.

To get more out of your fuel load, consider inviting friends to bake together. Pot-luck pizza parties or baking days where everyone brings dough or batter can be a lot of fun.

Specialty Oven Designs:

To customize an earthen oven for your particular baking needs, consider any of the following:

- Adding more insulation will help improve the oven's efficiency. Thicken the perlite to 4" or more, or add a second layer to your existing oven and top with another layer of earthen plaster. Make your plinth wide enough to support these thicker walls.
- For longer bake times, consider more thermal mass. Thicker mass will heat, and cool, more slowly; thinner mass, faster. Our oven's 2” of thermal mass is enough for a couple of hours' baking. Adding 4" or more would increase the pre-fire needed, and the baking time, to over 4 hours.
- For shorter firing times, consider less thermal mass. With careful plastering technique, you can make the lining as thin as ½", for an oven that heats quickly for single-batch cooking. (Thinner ovens also cool quickly, so have everything ready to bake at once; a thin oven will work for pizza, but may not store enough heat for bread or roasts.)
- For flatter foods, such as pizza and flat-breads, a lower dome can be built. This uses less material, wood, and space, but also limits the space for visibility and handling. Mock up the shallower catenary arches for each profile using a chain, and remember to lower the bake door's height to scale.
- Daily use allows any oven to operate with better fuel efficiency, due to stored heat.
- For a large-scale operation such as a pizzaria or re-enactment village, consider a larger oven, or multiple ovens for continuous baking. Commercial ovens may be 4 to 6 feet or more in diameter, with up to a foot of thermal mass; or built like arched tunnels, stacked in rows in a bakery wall.

Calculations for Changes:

If you want to change the dimensions (making the oven/stove bigger or smaller), remember that the volume will change much more than the length. Volumes go by the cube of the distance.

For example, if you add 6” to the interior diameter of the oven (change from 30 inches to 36”), you change the interior volume (and the sand mold) from 4 cubic feet to 7 cubic feet, and the average surface area from 14 to 19 square feet. Plan on using a LOT more materials for even a small increase in size.

If you like, you can try to calculate the additional materials needed for your planned change.
As a geometry refresher:
Π (pi) is that 3.1416 number for circle stuff.
r=radius (distance from the middle to the edge of the circle, or 1/2 the diameter/distance across),
l=length, w=width, h=height
r^2 means r times r; r^3 means r*r*r

Volumes, Surface areas, and Perimeters:

Half-sphere volume = $2/3*\Pi*r^3$	Half-sphere SA: $2*\Pi*r^2$.
Cylinder volume = $\Pi*r^2*h$	Cylinder SA: $2*\Pi*r*h$
Box volume = l*w*h	Box SA: sum of all the surfaces = 2(l*w + w*h + h*l)
Circle area: $\Pi*r^2$	Circle circumference: $2*\Pi*r$

Rectangle area: length*height (or width) Rectangle perimeter: 2(l+h)

Although the shapes are not spherical, a sphere makes a good approximation for rough calculations. Surface areas and perimeters are useful for rough calculations on layers (like insulation or plasters): instead of subtracting one volume from another, you can multiply the surface area times the thickness. (Use the outside radius of the layer to allow some material to spare.)

The volume of any clay-based material will usually be similar to the volume of aggreate alone - that is, use your calculations for total sand volume, and then factor in another 1/3 of that total volume for clay that will stick between all that sand.

Round up (or add at least 10%) to allow for compaction, waste, and any spills or lumps. I often order double the sand that I think I will need, just to save time and dump-truck fees if I make a layer thicker than I intended. But then, we're always making cob projects, filling potholes, or laying brick and drainge paths somewhere. Even a large pile of sand or gravel just withers away somehow.

Thank you for choosing our plans. We would love to hear about your project. We also offer consulting, custom designs, workshop instruction, and work-party facilitation for interested owner-builders. You can reach us with any questions or comments at: questions@ErnieAndErica.info

– Ernie and Erica Wisner
www.ErnieAndErica.info